

RADARSAT



*Annual
Review
1999
2000*

RADARSAT-1: The Canadian Space Agency's first Earth observation satellite equipped with a powerful synthetic aperture radar (SAR) instrument. The RADARSAT-1 satellite operates day and night, in all weather, through cloud cover, smoke, haze and darkness, to acquire high quality images of the Earth.

Industry, government and scientific organizations have teamed up to develop, manage and deliver the RADARSAT-1 Program. Combined, the individual strengths of the Program partners (see below) form both an effective strategic and working alliance to provide exceptional SAR imagery and service to clients the world over.

Canadian Space Agency (CSA)
Space Operations
Satellite Operations Directorate

Space Technologies

Natural Resources Canada
Canada Centre for Remote Sensing (CCRS)

RADARSAT International (RSI)

National Aeronautics and Space
Administration (NASA)/National Oceanic and
Atmospheric Administration (NOAA)

Canadian Provinces

Canadian Industry

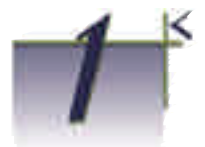
- Owns and operates RADARSAT-1
 - Controls RADARSAT-1 in space, plans SAR data acquisition and delivery, and tasks RADARSAT-1 ground systems
 - Supports commercial and government clients including the Canadian Ice Service, Department of Fisheries and Oceans, and the Department of National Defense
 - Undertakes data commercialization and applications initiatives
 - Conducts advanced SAR research and development and technology commercialization
-
- Operates Canada's two RADARSAT-1 receiving stations
 - Oversees pre-processing, recording and archiving of RADARSAT-1 data
 - Conducts applications research
-
- Processes, markets and distributes RADARSAT-1 data commercially through distributors and network stations
 - Owns and operates the Canadian Data Processing Facility (CDPF)
-
- Launched RADARSAT-1
 - Distributes RADARSAT-1 data to the United States government through the Alaska SAR Facility
-
- Contributed Program funding
 - Pre-purchased RADARSAT-1 data
-
- Designed and built the RADARSAT-1 satellite and ground system
 - Contractually supports RADARSAT-1 operations and maintenance
 - Develops and sells RADARSAT-derived products and services

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Front cover: RADARSAT-1 imagery of Trincomalee, Sri Lanka and Svalbard, Norway was used to create the montage featured on the front cover. The Trincomalee image was the first data acquired in the year 2000 by CRISP, the RADARSAT-1 network station in Singapore. With its discernible dragon likeness, the image heralds both the new millennium and the Year of the Dragon. The Svalbard mosaic subsection showcases the ability of RADARSAT-1 to map ice-capped islands in polar regions of the world.

Trincomalee RADARSAT-1 data © Canadian Space Agency 2000. Received and processed by CRISP, National University of Singapore. Distributed under licence by RADARSAT International (RSI). Provided by CRISP and RSI. Svalbard RADARSAT-1 data © Canadian Space Agency 1997. Received and processed by TSS. Distributed under licence by RADARSAT International (RSI). Produced and provided by TSS and RSI.



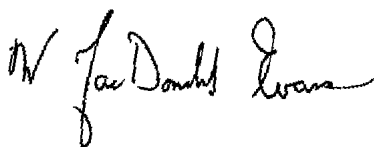
A New Paradigm of Remote Sensing

On the threshold of this new millennium, we reflect on a century of extraordinary achievements in science and technology. History denotes how Ford's Model-T changed the way we travelled, how Bell's "electrical speech machine" transformed the way we communicated, and how Neil Armstrong's "one small step" converted ideas once reserved for science fiction into reality.

The same can be said about RADARSAT-1. RADARSAT-1 has pioneered revolutionary ways to manage and monitor the Earth's resources. Conceived by the ingenuity of Canada's scientific community and built by the expertise of Canadian industry, this sophisticated remote sensing system has become an important contributor to the success of our nation's space program.

After four years of operations, RADARSAT-1 has helped to make Canada a world leader in the processing of satellite remote sensing data. Canadian industry holds an increasing share of the world market for space-based information products. Employment and revenues are growing at a sustained rate of 20 percent annually and revenues from export sales have grown to 40 percent.

Canada is exceptionally well positioned to respond to the rapidly emerging international demand for more advanced techniques in environmental monitoring and natural resource protection. This impressive status will only intensify as we gear up for the launch of RADARSAT-2 and enter a new era of opportunity for Earth observation technology.



W.M. (Mac) Evans
President
Canadian Space Agency

Operational Excellence Pays Dividends

Recognized globally for its responsiveness and unique imaging capabilities, RADARSAT-1 continued to prove its versatility in fiscal 1999/2000, supported by an expert team who manages the world's most sophisticated civilian SAR satellite.

As a result of the experience gained in managing RADARSAT-1, CSA's Satellite Operations was able to collaborate with France and support the 1999 Launch and Early Operations Program (LEOP) of HELIOS-1B — taking the first steps in adopting a multi-disciplinary, multi-satellite approach and bringing a generic capability to bear on a wide range of CSA flight hardware. In addition, the extensive preparations for the year 2000 paid off with no interruption in RADARSAT-1's operations at the calendar turnover. These solid abilities assume greater significance with the scheduled launch of RADARSAT-2 in 2002; RADARSAT-1 will be counted on to perform well past its original design lifetime of five years.

The unveiling of the first complete high-resolution radar map of Antarctica captivated the world. Selected as one of the top ten science stories of 1999 by Discovery Channel Canada, this compelling mosaic is helping scientists understand global climate changes. In addition, a new Canada-wide mosaic was produced, demonstrating how synoptic views can be deployed to monitor large areas.

Improved image request processing as well as the availability of a comprehensive data archive are helping CSA and its Program partners meet increased client needs for imagery, especially for time-sensitive disaster events. Moreover, the value-added industry is exploiting the growing demand for RADARSAT-derived products and services — evidence of RADARSAT-1's continued robustness in satisfying global information needs.



Rolf Mamen
Director General
Space Operations
Canadian Space Agency



The RADARSAT-1 Program: People Make the Difference

CSA's Satellite Operations Directorate operates and manages the RADARSAT-1 Program. In 1999, Satellite Operations conducted a mid-term review in collaboration with the Program partners to obtain a clear picture of the status of the RADARSAT-1 mission since its launch in November 1995.

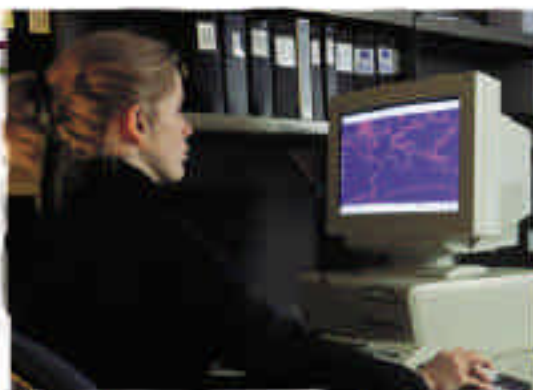
At the conclusion of the review, Surendra Parashar, Director, Satellite Operations, noted that the RADARSAT-1 Program was and continues to be a resounding success. "Not only has the RADARSAT-1 Program clearly met its objectives even at the mid-point of the mission, it has pioneered technical innovation (e.g. multi-mode SAR), operational service delivery to clients (such as rapid and reliable system response), commercialization, and partnerships in Earth observation," said Mr. Parashar. "Furthermore, the Program's success is due in large part to the coordinated efforts of hundreds of professionals in Canada and abroad who contributed to the conception and development of the mission as well as the hundreds more now involved in the operational phase."

Forming an integral part of this dedicated team are the people of the Satellite Operations Directorate, based at CSA in Saint-Hubert, Quebec. Along with the data calibration, management, and commercialization groups, the Directorate encompasses the Mission Planning group, which operates the Mission Management Office (MMO) 16 hours a day, year-round. Each day, 15 mission planners prioritize customer orders from five RADARSAT-1 order desks and develop plans for data acquisition, onboard recorder usage, data reception, data processing

RADARSAT-1
Satellite
Control
Centre



RADARSAT-1
Order Desk
Service



and/or archiving. Then the mission planners generate Payload Command Data (PCD) files and transmit them to the System Operation group.

With 50 professionals, including satellite controllers, the System Operation group first checks the PCD files and then packages them for uplink to RADARSAT-1 during its morning and evening passes, using the telemetry, tracking and command antenna located at CSA in Saint-Hubert, Quebec or in Saskatoon, Saskatchewan. The PCD files automatically begin executing the defined payload sequences the next imaging day. Twenty-four hours a day, 365 days a year,

System Operation staffs send commands to RADARSAT-1 and closely monitor the health and safety of the satellite. As a result of the integrated efforts of these two key operational groups, working together with value-added suppliers, data distributors and sales staff, other order desk operators, and data reception and processing operators, the RADARSAT-1 satellite is efficiently satisfying customer orders from nearly 60 countries.



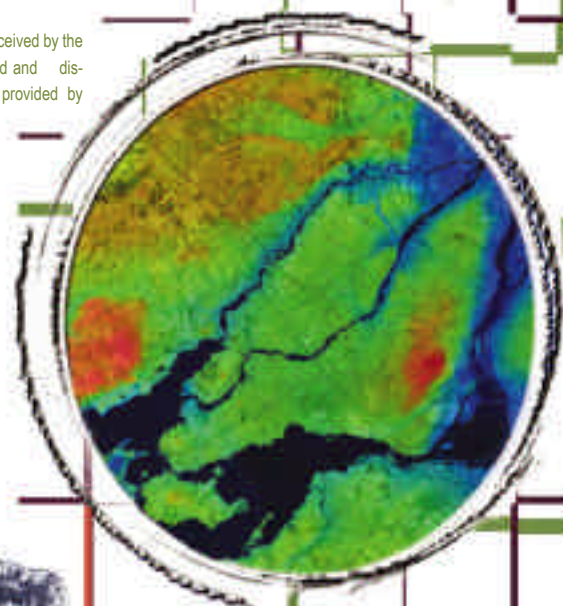
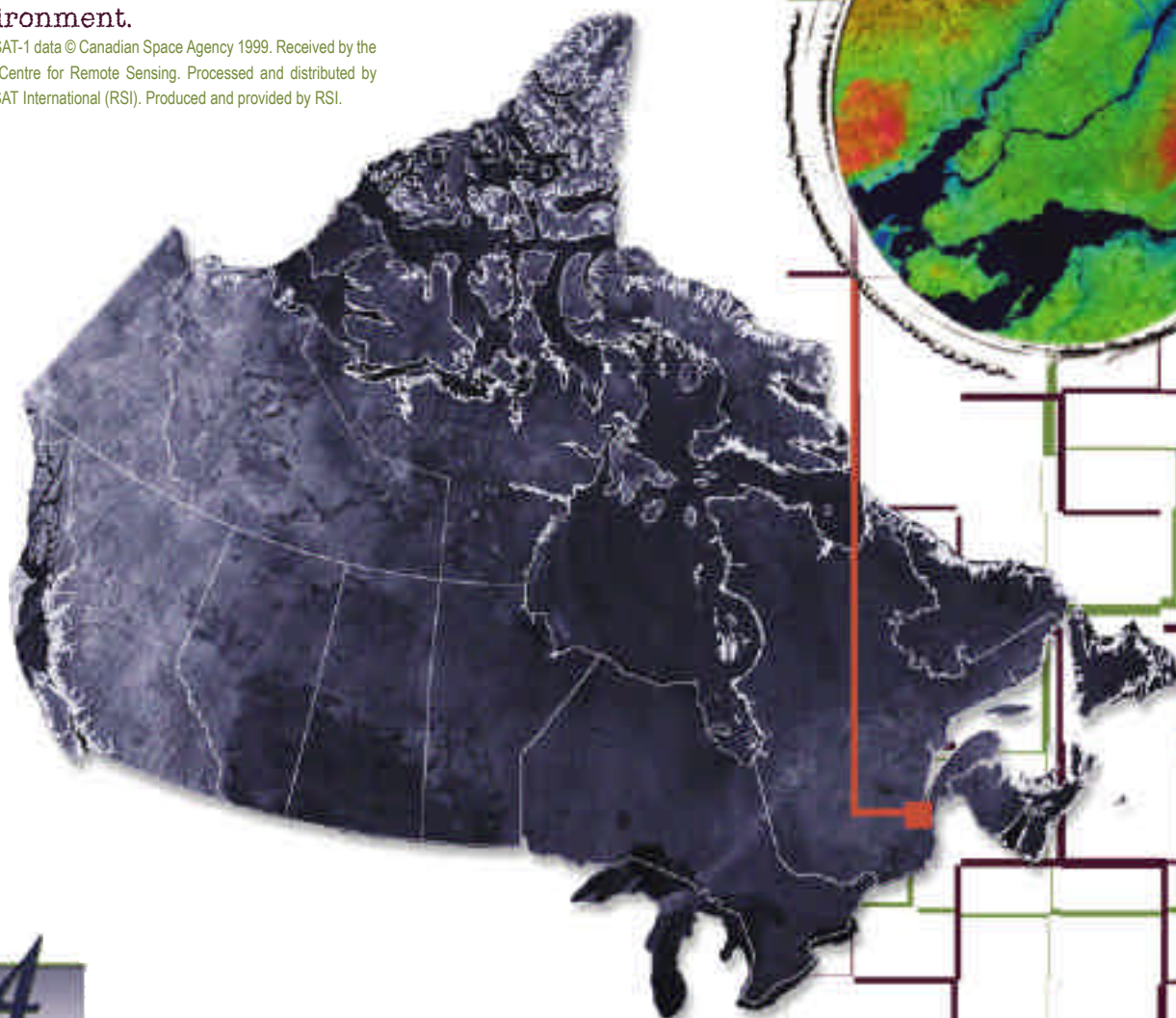
The RADARSAT-1 System: Improving Operational Efficiency

The first complete near-instantaneous view of Canada was produced last year as a joint project between RSI and CSA, under the RADARSAT-1 Background Mission program. This unique mosaic comprises 276 ScanSAR Narrow images, which were acquired over seven days during the winter of 1999. Such large overviews play a valuable role in managing the Earth's natural resources and monitoring the environment.

RADARSAT-1 data © Canadian Space Agency 1999. Received by the Canada Centre for Remote Sensing (CCRS). Processed and distributed by RADARSAT International (RSI). Produced and provided by RSI.

Two orthorectified Fine scenes were joined to create a 100 x 50 kilometre mosaic of Montréal, Québec. The distortions in the relief were corrected using a DEM and then the DEM was colour-coded. The mosaic is best viewed with ChromaDepth 3D glasses.

RADARSAT-1 data © Canadian Space Agency 1999. Received by the Canada Centre for Remote Sensing (CCRS). Processed and distributed by RADARSAT International. Produced and provided by CCRS.





Improving operational efficiency and client responsiveness remained top priorities in 1999. A key enhancement implemented by Mission Planning was reducing the Payload Command Data (PCD) planning baseline from 53 hours to 29 hours, allowing clients for the first time to routinely submit their requests only 29 hours before imaging. This major improvement eliminated the time and risk involved in manually changing a planned PCD to accommodate last-minute, urgent requests. Furthermore, the 1999 upgrades to the Mission Management Office database hardware have resulted in a faster and more powerful system, increasing efficiency in planning, tracking, product delivery and multi-tasking.

Monitoring Image Quality

Throughout 1999, the RADARSAT-1 calibration maintenance program continued to be fully operational. The radiometric calibration performance of each calibrated beam was monitored regularly and adjustments in processing parameters were made as needed.

The database of image quality parameters was extended to reflect measurements made in 1999 on numerous images of precision transponders and the Amazon Rainforest. Visualization tools were further enhanced, incorporating statistical methodologies for tracking changes in the radiometric performance of calibrated beams over time. As in previous years, resolution-related measures were better than specifications, and location accuracy was deemed excellent.

Demonstrating Robustness and Stability

After 18 months of concerted effort, including an exhaustive end-to-end operational demonstration conducted by CSA with CCRS and RSI, the RADARSAT-1 system entered the year 2000 without incident.

Although no attitude control instigated outages occurred during the 1999 eclipse period, variations in momentum wheel speed control and bearing temperature were observed late in the season. To avoid a wheel failure, the wheel was turned off and control was successfully switched to the redundant wheel in early fall. The system continues to operate nominally.

Dramatic reductions in data losses from payload anomalies were realized by improving recovery procedures. In particular, changes in extracting payload telemetry resulted in a threefold reduction in the expected frequency of the loss of block telemetry, the most common payload anomaly.

System Operation successfully supported the LEOP of the HELIOS-1B satellite, launched by CNES of France from Kourou in December 1999. Accomplished with only minor modifications to the TT&C system, this cooperative mission demonstrated the flexibility and capabilities of both the TT&C system and the operational personnel in Saint-Hubert, Quebec and Saskatoon, Saskatchewan, and stands as a model for future international collaboration.

1999 acquisition requests	20,755
1999 estimated minutes of data	37,516
1999 orbits	5,231
1999 estimated OBR imaging requests	5,144

Maximum minutes of on-time per orbit	32
Average system performance	96.7 %
Number of playbacks per day	3.3

Total number of acquisitions	72,322
Total estimated minutes of data	137,353
Total orbits	22,999
Total estimated OBR imaging requests	33,607



RADARSAT-1 Stations Cover the World

Centre for Remote
Imaging, Sensing
and Processing
(CRISP)
Singapore, Republic
of Singapore



CENTER for REMOTE IMAGING,
SENSING and PROCESSING
THE NATIONAL UNIVERSITY of SINGAPORE

Remote Sensing
Satellite Ground
Station (RSGS)
Beijing, China
Image: Hong Kong and
Shenzhen City, China
(Wide 1)



Defence
Evaluation
Research
Agency
(DERA)
West Freugh,
Scotland

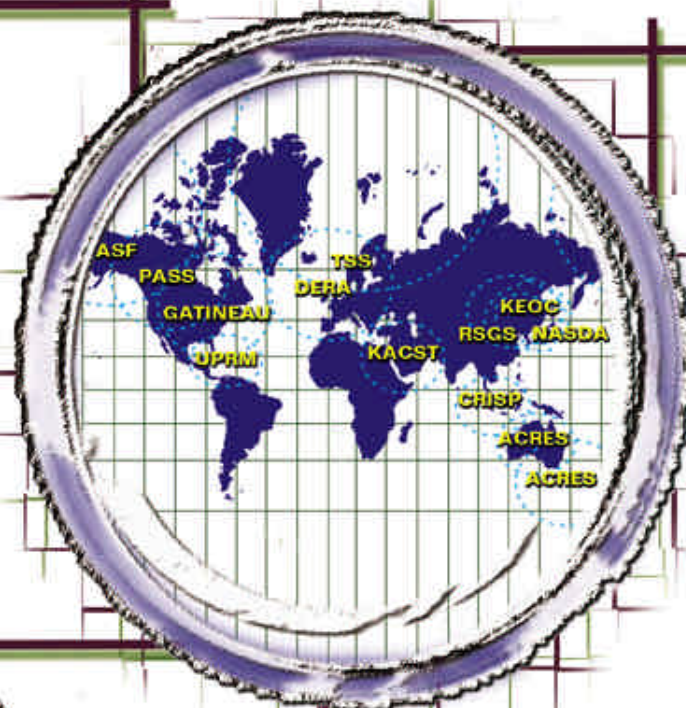
Image: Odra River, Poland
(Standard 7)

DERA



ACRES

Australian Centre for
Remote Sensing (ACRES)
Alice Springs, Australia
and Hobart, Tasmania
Image: Sydney, Australia (Fine 1)



King Abdulaziz City for
Science and Technology
(KACST)
Riyadh, Saudi Arabia
Image: Jeddah, Saudi Arabia (Fine 3)



National Space Development
Agency of Japan (NASDA)
Kumamoto, Japan

Image: Tokyo and Mount Fuji, Japan
(ScanSAR Wide)



Tromso
Satellite
Station
(TSS)
Tromso,
Norway



Korea Earth
Observation
Centre (KEOC)
Seoul, Korea

Image: Japan (Standard 4)



University
of Puerto
Rico at
Mayaguez
(UPRM)
Mayaguez,
Puerto Rico

Station Certification in Progress

Eagle Vision 1 Mobile Station
Germany

National Research Council of
Thailand (NRCT)
Bangkok, Thailand

Planned Network Stations
Instituto Nacional de Pesquisas
Espaciais (INPE)
Cuiaba, Brazil

Istanbul Technical University (ITU)
Istanbul, Turkey

*Images and logos for the
Canadian and U.S. operational
RADARSAT-1 stations are not pre-
sented here. These stations are the
Gatineau Satellite Station (GSS),
Prince Albert Satellite Station
(PASS), Alaska SAR Facility (ASF),
and McMurdo Station.

RADARSAT-1 data © Canadian Space Agency
1997, 1999, 2000. Images presented in this
section were received and processed by the
respective network stations. Images distributed
under licence by RADARSAT International
(RSI). Images produced and provided by the
respective network stations and RSI.

International

With the operations certification of the Puerto Rico network station in January 2000, the total number of international network stations grew to ten. During 1999, network stations in both Saudi Arabia and South Korea achieved product certification, and the Australian Centre for Remote Sensing upgraded its data processor in Canberra to achieve product certification for ScanSAR.

Portable ground stations continue to play a role in receiving and processing RADARSAT-1 data. Canada's SENTRY system, a mobile station based in Halifax, Nova Scotia, achieved product certifiable status, and Eagle Vision 1, a U.S. mobile station based in Germany, is expected to achieve operations certification by early spring.

Canada

In 1999, CCRS devoted significant effort to Y2K readiness, which successfully resulted in the CCRS-operated ground stations in Gatineau, Quebec and Prince Albert, Saskatchewan achieving Y2K compliance. Also, CCRS and CSA initiated upgrades to the ground system infrastructure in support of the upcoming RADARSAT-2 program.

Nearly 70 percent of the RADARSAT-1 archive data received by these two stations now resides in the CCRS RADARSAT-1 archive of raw data, which was established last year. The CCRS RADARSAT-1 archive of real-time and onboard recorder data, created in 1995, is more than 62 terabytes in size, growing at an annual rate of approximately 15.5 terabytes.

Background Mission Enriches RADARSAT-1 Archives

Located in the North Atlantic, the glacier-covered island of Jan Mayen is dominated by a volcanic peak that is cloud-free for only a few days each year. This multi-season image shows the ability of RADARSAT-1 to see through clouds and acquire imagery regardless of weather and time of year. Such temporal coverage is valuable in observing variations in glacial extents that may indicate climate change.

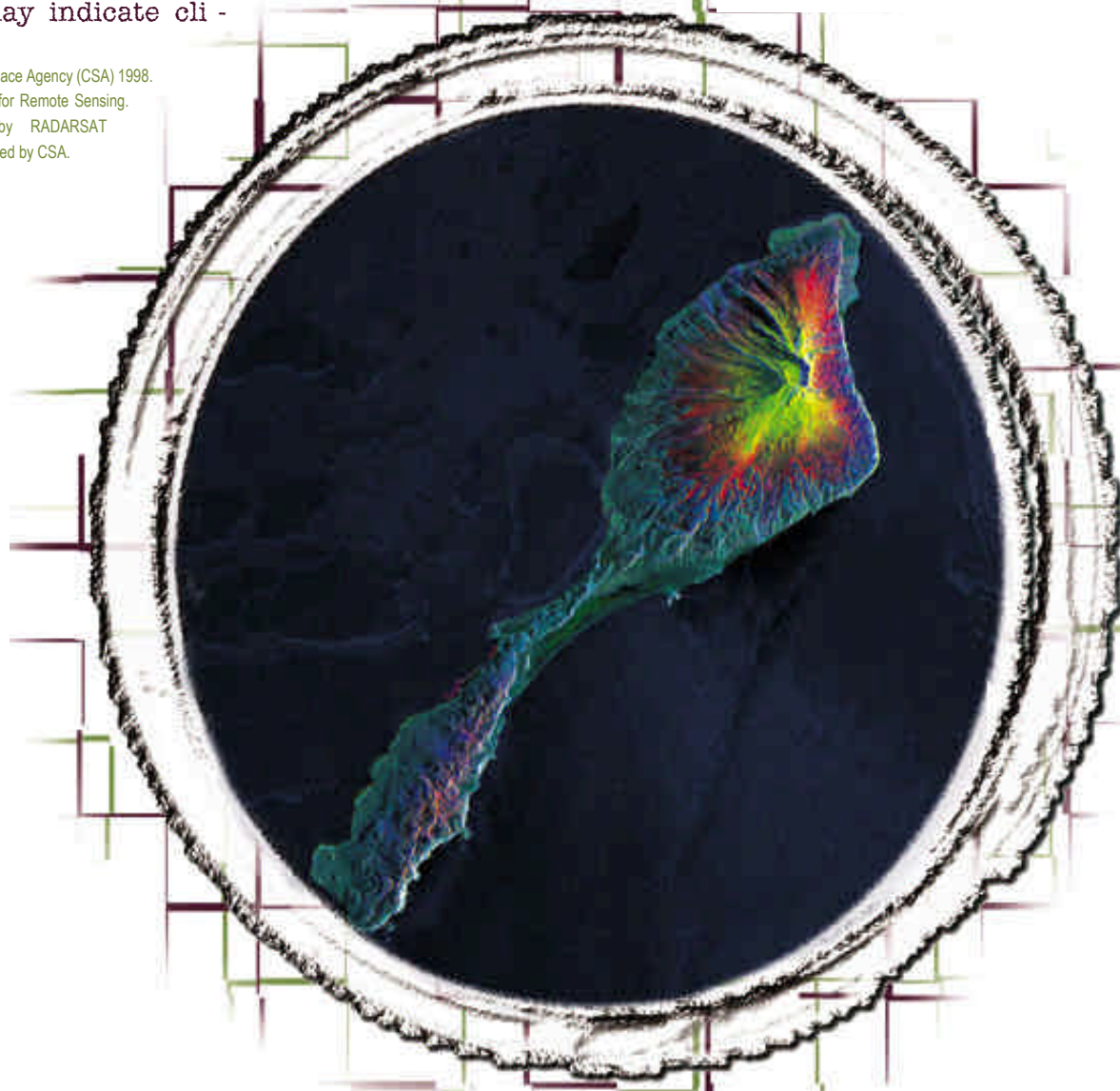
RADARSAT-1 data © Canadian Space Agency (CSA) 1998.
Received by the Canada Centre for Remote Sensing.
Processed and distributed by RADARSAT
International. Produced and provided by CSA.

Data acquisitions made under CSA's Background Mission project continue to enrich RADARSAT-1 archives, supplying uniform global data sets for use in a diverse range of applications. Seasonal ScanSAR Narrow coverage of North America, including a week's winter coverage of Canada, was completed in 1999 — generating the first complete mosaic of the country. The mosaic demonstrates RADARSAT-1's ability to deliver seasonal

shots" of large surfaces of the Earth, which can be used for environmental and resource monitoring.

Collecting land stereo data remained an important mission activity throughout 1999.

Australia: After completing Standard 7 coverage, Standard 4 coverage was acquired to create a seasonally coherent stereo data set of the entire continent.



China: Standard 7 coverage of this country and the adjoining regions is now complete.

Saudi Arabia: Standard 7 coverage of the Saudi Arabian peninsula as well as surrounding areas in the Middle East and Africa is now available.

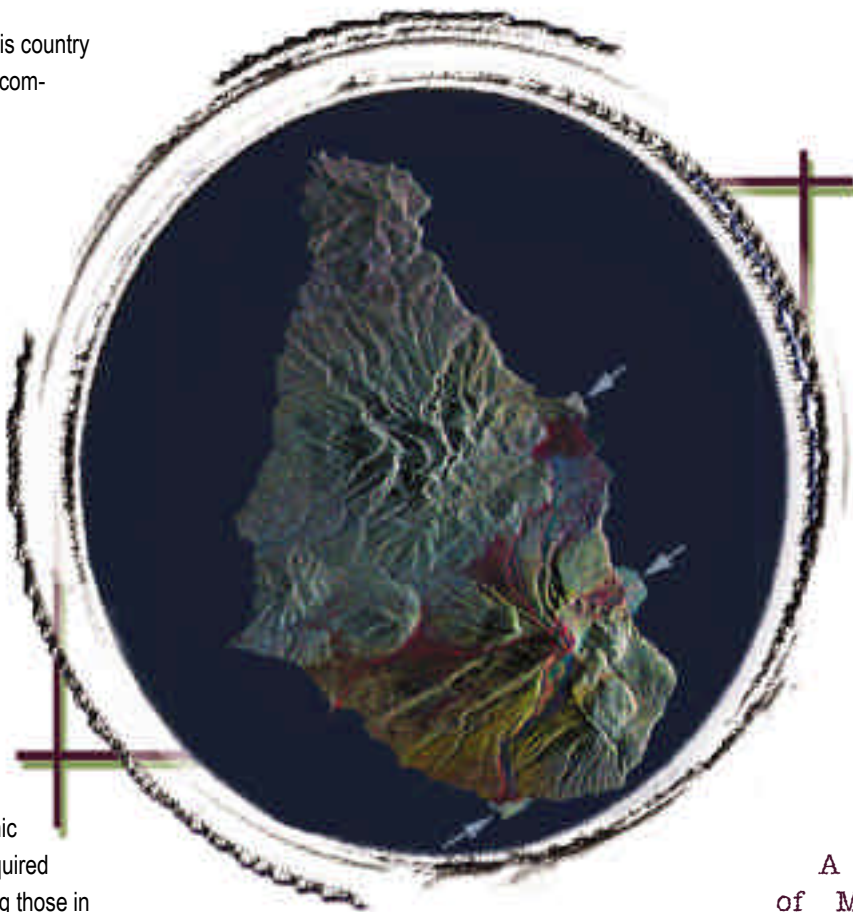
Stereo coverage of these areas with one other RADARSAT-1 beam mode (Standard 4 or Wide 2) is now in progress.

Over the past year, additional multi-temporal data sets were acquired over the world's oceanic islands, and new data were acquired over some larger islands, including those in the Caribbean. These data sets are proving their worth in the analysis of landcover and landform changes induced by natural phenomena or anthropogenic factors.

Some 170 major cities of the world have now been imaged with RADARSAT-1's 10-metre resolution Fine beam. This one-of-a-kind coverage will serve as historical data for future studies on urban growth or decay.

By continually imaging different regions of the world, the Background Mission is also supplying valuable acquisitions of imagery preceding nat-

ural disasters. In 1999, reference images for floods, earthquakes, and volcanic eruptions were provided. In addition, a special Background Mission campaign was undertaken to cover the 1999 hurricane season over the West Atlantic and along the Gulf Coast; a total of 191 ScanSAR Wide swaths were acquired.



A composite image of Montserrat, West Indies shows the formation of pyroclastic deltas (arrows) in the sea as a result of the flow of volcanic material along river valleys east and southwest of the main Soufriere Hills volcano, located in the southern part of the island. The accumulation of volcanic ash and other pyroclastic material impart a characteristic radar tone to the southwestern slopes of the island.

RADARSAT-1 data © Canadian Space Agency (CSA) 1996, 1997, 1998. Received by the Canada Centre for Remote Sensing. Processed and distributed by RADARSAT International. Produced and provided by CSA.

ADRO-1 Follow-on and ADRO-2



Created from ScanSAR and Standard data acquired in two separate years, this multi-temporal image is being used to map wetland areas in the Danube River Delta. On the Ukrainian side, the delta is still being formed, and 80 percent of it is permanently submerged or submerged during flooding. A network of shallow lakes, some of which are very large, can be seen. These are connected by multiple natural and artificial channels. Only pre-delta or dammed areas, some cultivated, and dune ridges covered by dense deciduous forests emerge from the waters.

RADARSAT-1 data © Canadian Space Agency 1997, 1999. Received by the Canada Centre for Remote Sensing. Processed and distributed by RADARSAT International. Produced and provided by LBGI and the University of Montréal Remote Sensing Laboratory.

ADRO-1 Follow-On

With the success of the ADRO-1 Symposium in October 1998, CSA's Satellite Operations and its program partners NASA and RSI unanimously agreed that the advances made in radar remote sensing under this enterprising applications program warranted further investigation.

As a result, CSA identified in 1999 key areas for subsequent evaluation and requested new demonstration products from six research teams.

Wetland Mapping

The University of Montreal teamed up with LBGI (Le Bureau Geo-Info) to provide examples of how RADARSAT-1 data can be used to delineate wetland areas. This work generated an educational CD-ROM and a poster showing work in both Canada and Romania.

GeoTechnical Evaluation of Hazardous Regions

Under controlled conditions, RADARSAT-1 data can produce outstanding interferograms, and new applications continue to evolve. Atlantis Scientific Inc., working with EBA Engineering Consultants Ltd., demonstrated the use of RADARSAT-1 data using repeat pass interferometry over a known hazardous area in the Canadian Rocky Mountains that has been subject to landslides and unstable slopes.

Soil Moisture Mapping

Noetix Research Inc. expanded on their agriculture work to provide material that illustrated how RADARSAT-1 can assist farmers with in-field soil moisture maps. These products can be used in precision farming practices to help set fertilization patterns on a per field basis.

Land Use Mapping

GPA (Le Groupe Perspective D'Avenir Inc.) and the University of Montreal prepared an educational CD-ROM to illustrate how to prepare land-use maps using RADARSAT-1 data and how the data can assist in large-scale mapping programs and municipal applications.

Ocean Current Monitoring

Shell Oil, in collaboration with Atlantis Scientific Inc., extended previous research in mapping ocean currents in areas of the Gulf of Mexico where oil seeps had been previously detected. The results demonstrated that RADARSAT-1 could be used successfully in areas where currents move the surface oil.

ADRO-2

Building on the achievements of the ADRO-1 and the ADRO-1 Follow-on initiatives, CSA's Satellite Operations and NASA have launched an ADRO-2 program. This new program places a strong emphasis on applications research and demonstration projects that make use of RADARSAT-1's extensive data archive, which is now available thanks to four years of operational use of RADARSAT-1.

The Antarctic Mapping Mission: Mosaic of an Icy Continent

In October 1999, CSA's Satellite Operations and NASA unveiled the world's first, high-resolution radar map of Antarctica. The digital mosaic was constructed under a NASA Pathfinder Project awarded to the Byrd Polar Research Center of Ohio State University (OSU). Taking two years to process the 25-metre pixel size data into a standard map projection, the mosaic comprises more than 4 500 RADARSAT-1 scenes acquired during 18 days of the RADARSAT-1 Antarctic Mapping Mission 1, which took place in September and October 1997.

The mosaic (see overleaf) provides an extraordinary glimpse of the southern continent. Coastal margins appear bright in the aftermath of summer melt. The resulting high contrast between the coastal snow and the sea ice covered waters also makes for easy identification of the Antarctic coastline — an important benchmark for gauging future changes in the terminus position of the vast ice sheet.

The interior of the ice sheet varies between very bright and very dark tones due to differences in accumulation rate. Low accumulation areas are bright because snow grains remain longer near the surface. As snow grains age, they become larger through vapour transport processes, and larger grains are better radar scatterers.

Long, curvilinear ribbons wind across East Antarctica. The ribbons are highly correlated with ice divides inferred from measurements of surface topography. Ice divides are equivalent to the boundaries of watersheds in more northern regions and reveal information about the seaward path of snowflakes falling within each

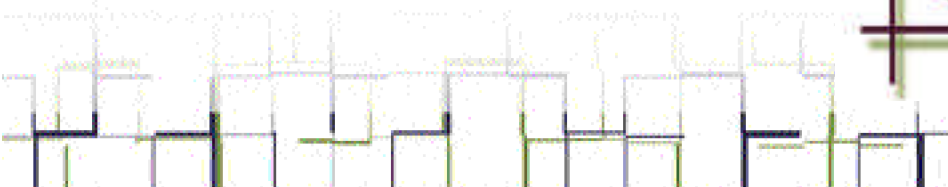
catchment area, which aids in determining whether local areas of Antarctica are thinning or thickening.

The RADARSAT-1 imagery reveals the extent of a previously unknown network of ice streams in East Antarctica. "We were surprised to see a complex network of ice streams reaching deep into the heart of East Antarctica," said Kenneth Jezek, Professor at OSU's Byrd Polar Research Center. "These rivers of ice wind hundreds of kilometres from the interior of East Antarctica to the Filchner Ice Shelf where they discharge over 82 cubic kilometres of ice per year. Because ice streams are the most energetic processes found within the ice sheet, they are a key indicator of the amount of ice lost to the sea, which in turn is a control on global sea levels."

The RADARSAT-1 Antarctic Mapping Project is truly an international collaboration. Along with Canada and the United States as the leading partners, the project received assistance from Great Britain, Germany, Australia, New Zealand, Argentina, and Japan. The results are directly benefiting the work of scientists pursuing questions about the role of Antarctica in global climate change. Further-more, the imagery is providing people around the world with a superlative view of a remote and beautiful part of the Earth.

Bright areas in the image represent the Amundsen-Scott Station operated by the U.S. National Science Foundation. The line extending from the station to the lower right is a "highway" to an abandoned antenna site. Above the station is a 14 000-foot skiway, which appears as a bright band. Between the skiway and the station is the geographic South Pole, the only site visible on every pass of RADARSAT-1, which was invaluable in constraining the geometry of the Antarctic mosaic.

RADARSAT-1 data © Canadian Space Agency 1997. Received by the Alaska SAR Facility (ASF), Canada Centre for Remote Sensing and McMurdo Station. Processed by ASF and RADARSAT International (RSI). Distributed by RSI and ASF. Produced and provided by the Byrd Polar Research Center of Ohio State University.



Antarctica Revealed

Large cracks have formed in the Ronne Ice Shelf where shearing stresses exceeded the strength of the ice, as the ice flows past Berkner Island and a smaller ice rise to the west. Nearly one year after this image was acquired, one such crack caused a slab of ice roughly the size of the U.S. state of Delaware to separate from the ice shelf.



**Ronne
Ice Shelf**

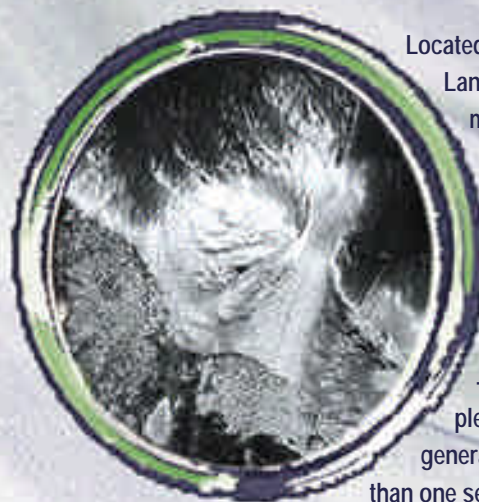


The West
Antarctica
Ice Streams are
rivers of ice within
the ice sheet itself.

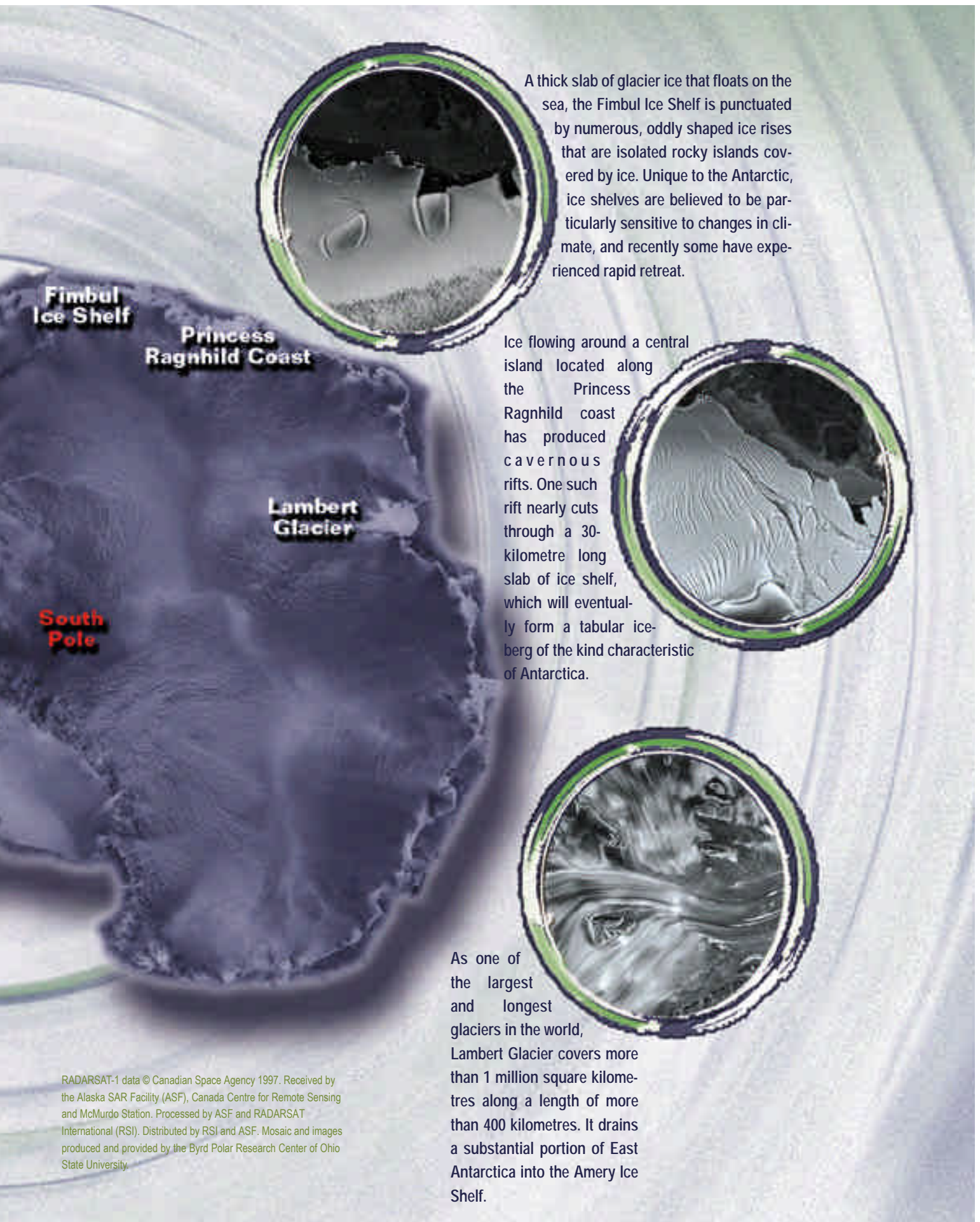
Downstream velocities approach 500 metres per year although ice bounding the ice stream may move at only 30 to 40 metres per year. Hundreds of kilometres in length, ice streams have very gentle slopes and are not easily detectable by observers on the surface.

**Ice
Stream B**

**Land
Glacier**



Located in West Antarctica, Land Glacier is one of many small glaciers that calve icebergs directly into the sea. The beautiful splay of small tabular bergs is frozen within a matrix of fast ice — sea ice that is coupled to the shore and generally persists for more than one season.



A thick slab of glacier ice that floats on the sea, the Fimbul Ice Shelf is punctuated by numerous, oddly shaped ice rises that are isolated rocky islands covered by ice. Unique to the Antarctic, ice shelves are believed to be particularly sensitive to changes in climate, and recently some have experienced rapid retreat.

Ice flowing around a central island located along the Princess Ragnhild coast has produced cavernous rifts. One such rift nearly cuts through a 30-kilometre long slab of ice shelf, which will eventually form a tabular iceberg of the kind characteristic of Antarctica.

As one of the largest and longest glaciers in the world, Lambert Glacier covers more than 1 million square kilometres along a length of more than 400 kilometres. It drains a substantial portion of East Antarctica into the Amery Ice Shelf.

RADARSAT-1 data © Canadian Space Agency 1997. Received by the Alaska SAR Facility (ASF), Canada Centre for Remote Sensing and McMurdo Station. Processed by ASF and RADARSAT International (RSI). Distributed by RSI and ASF. Mosaic and images produced and provided by the Byrd Polar Research Center of Ohio State University.

Disaster Management:

RADARSAT-1 Responds

Captured in this ScanSAR Wide image is Hurricane Floyd on September 14, 1999, when Floyd was off the U.S. east coast, north of the Bahamas. The relatively calm eye can be easily detected along with bands of intense precipitation around the eye and several pre-hurricane squall lines that also contain cells of intense precipitation. This unique sea surface view complements traditional, lower resolution IR cloud pattern imagery that is typically employed in hurricane observation and trajectory modelling.

RADARSAT-1 data © Canadian Space Agency 1999. Received by the Canada Centre for Remote Sensing (CCRS). Processed and distributed by RADARSAT International. Produced and provided by CCRS.

Offering unparalleled operational flexibility, selectable coverage products and fast data delivery, RADARSAT-1 is a proven system for deployment in disaster prevention, preparedness, management and recovery efforts. This means an increasing number of organizations are counting on RADARSAT-1 to respond to disasters and quickly supply vital information.

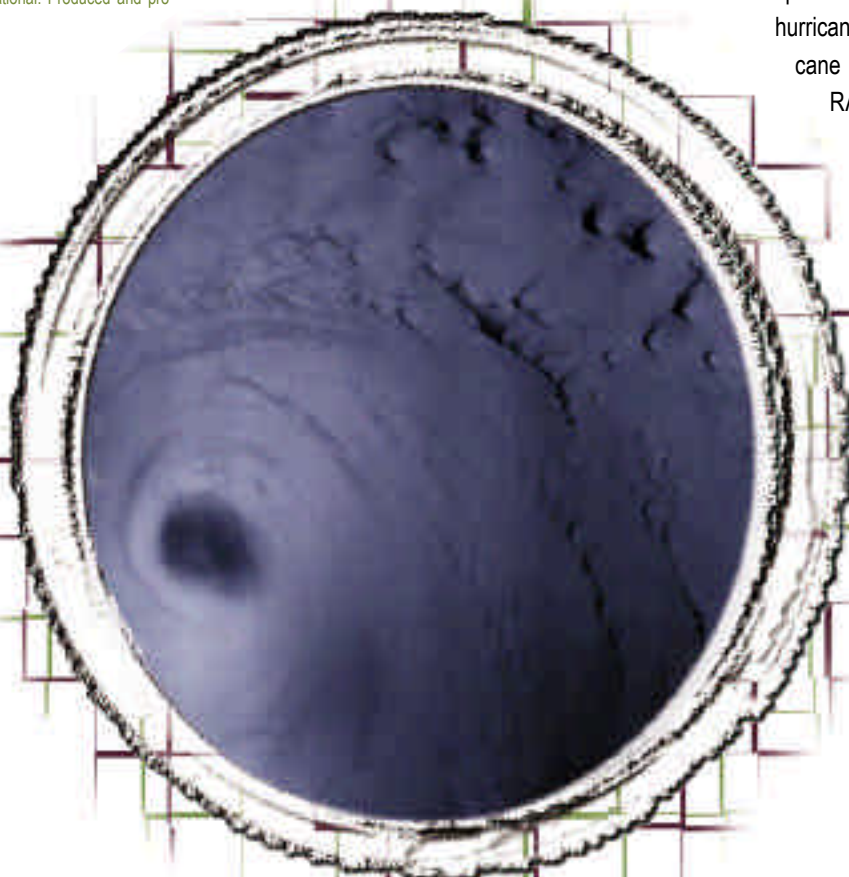
Covering disaster events was again a major activity for both CSA and RSI in 1999. Last year's implementation of the 29-hour PCD operational baseline enhanced RADARSAT-1's responsiveness to urgent disaster-related client requests. Since April 1, 1999, last-minute disaster-related requests grew to 85, a major portion of which were in response to catastrophic floods in China, France, India, Indonesia, Japan, Laos,

Mexico,

Thailand, Venezuela, and Vietnam. Through its Disaster Watch program, CSA's Satellite Operations participated with CCRS and NOAA in an innovative disaster monitoring initiative called Hurricane Watch. Under this cooperative program, ScanSAR Wide imagery of hurricanes was acquired during the 1999 Atlantic Basin hurricane season (typically May to November). In addition, CSA's Background Mission undertook a special campaign to acquire imagery for this program. The benefit of using ScanSAR Wide is twofold: it can supply both synoptic and small-scale views of the imprint of hurricanes on ocean surface roughness.

As tropical storms turned into hurricanes, CCRS and CSA Order Desk Services worked together to deliver maximum coverage of the areas of impact with the goal of acquiring coincident spacecraft and aircraft data of the eyes of the hurricanes. NOAA coordinated their P-3 hurricane penetration aircraft flights with RADARSAT-1 pass times, providing unique, high-wind speed validation opportunities. Producing a total of 225 RADARSAT-1 acquisitions, this program supplied images of the eyes of at least five hurricanes, including Cindy, Dennis and Floyd.

In addition, the European Space Agency (ESA) and CSA worked together during last year's hurricane season to further understand the potential added value of space techniques to civil protection by exchanging and using multi-satellite data from ERS-2, SPOT and



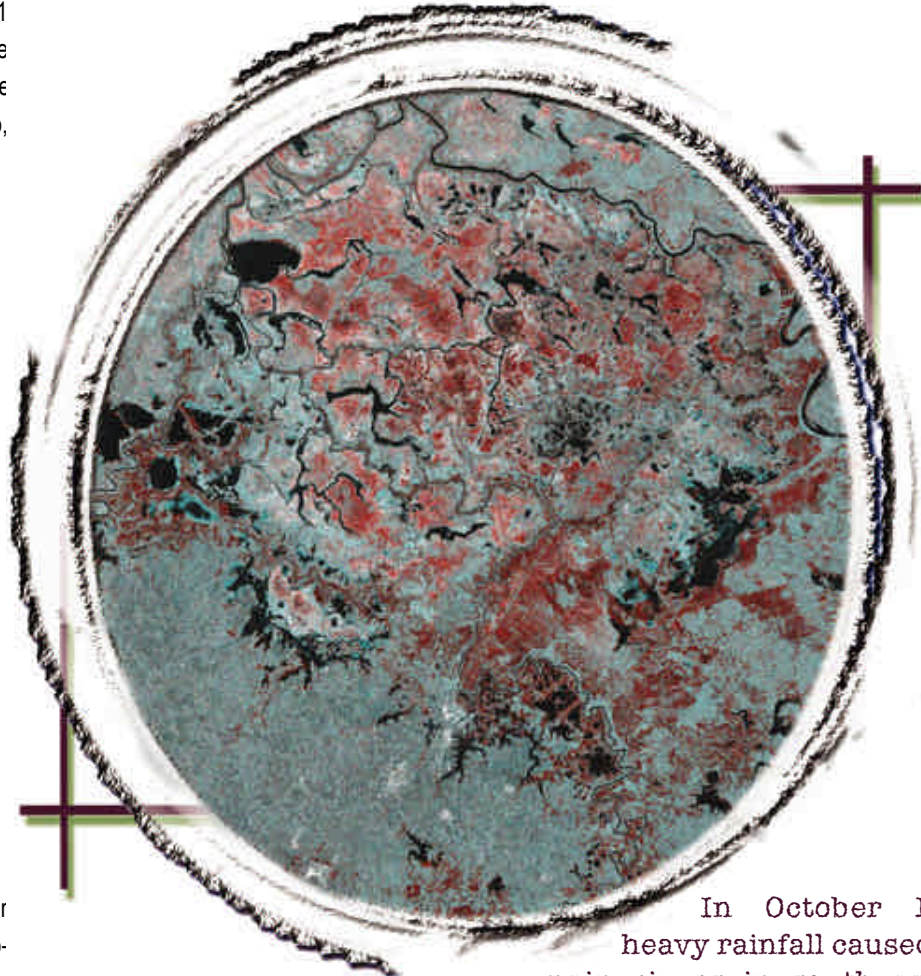
RADARSAT-1. To that end, RADARSAT-1 images of Hurricanes José and Lenny over the French islands Martinique and Guadeloupe were acquired, processed and delivered to ESA. Also, this international exercise explored the joint CSA/ESA mission planning capability for future cooperative initiatives.

CCRS implemented a National Advisory Working Group on Disaster Management in 1999. This working group will recommend to CCRS, CSA and Emergency Preparedness Canada research directions, policies and operational priorities related to the application of geospatial technologies, including RADARSAT-1, to disaster mitigation, planning / preparations, response / relief, and recovery phases of disasters.

Canada continues to support the Committee on Earth Observation Satellites (CEOS) through its participation in the Disaster Management Support Project, a multi-nation project that promotes the application of Earth observation satellite data to support disaster management. In 1999, Canada assumed the co-chair of the flood disaster working group.

During UNISPACE III, the United Nations space conference held in Vienna, Austria, July 19 – 30, 1999, CSA joined ESA and CNES in signing the Charter on Disaster Management. This charter aims to create and implement an integrated global space-based natural disaster management system by making maximum use of existing capabilities and filling gaps in worldwide satellite coverage. It also commits the signatories to

assisting organizations involved in disaster aid and rescue programs by setting aside a part of their resources, including satellites, instrumentation, ground equipment and archive resources. With its unique capabilities, RADARSAT-1 will serve as an essential component in Canada's efforts to fulfil its commitment.



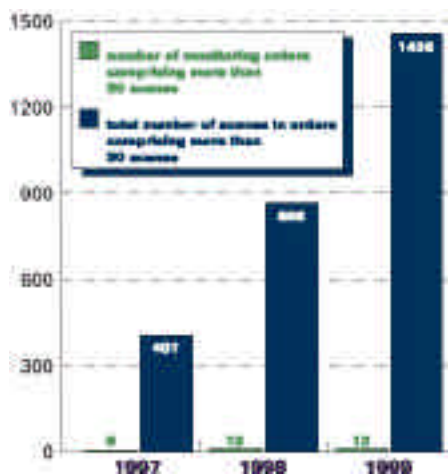
In October 1999, heavy rainfall caused the main rivers in southeastern Mexico to overflow, resulting in catastrophic floods and mud-slides. The province of Tobasco was one of the areas most severely damaged by the flooding as shown in this multi-tem-poral Standard 4 and 7 image.

RADARSAT-1 data © Canadian Space Agency 1997, 1999. Received by the Canada Centre for Remote Sensing. Processed and distributed by RADARSAT International (RSI). Produced and provided by RSI.

Client Service Spurs Commercial Success

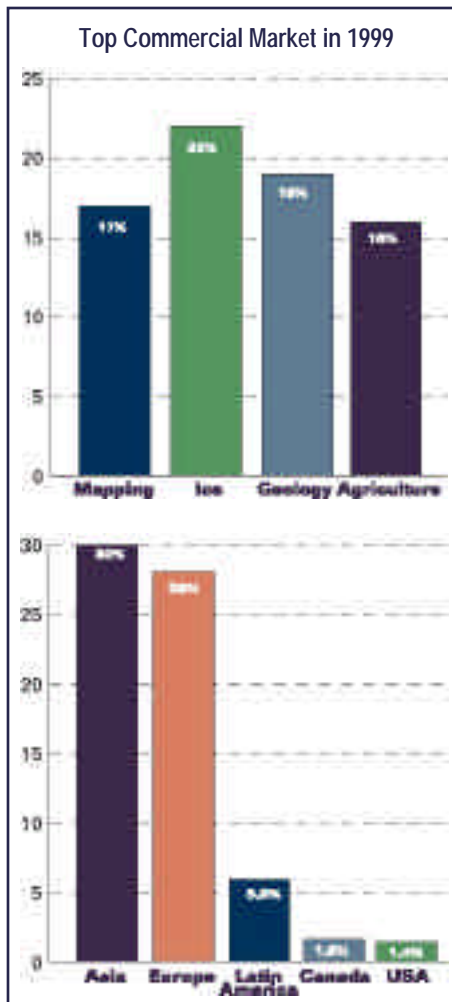
RSI continues to strengthen its position in the international Earth observation marketplace. Revenues in 1999 grew 30 percent over 1998, and a total of 8 280 scenes were processed. With the addition of 17 new distributors — including five in Canada — and one recently operational network station, RSI now serves a global community of more than 530 clients and partners in 57 countries.

According to RSI President Roland S. Knight, RSI's success in attracting new business while retaining existing customers is due in large part to the company's track record in meeting a broad spectrum of client needs. "Our client-oriented approach and ongoing flexibility are enabling us to enter new markets, win large volume orders and deliver unique information solutions. We can proudly say our clients enjoy access to a selection of high-quality SAR image products and enhanced client services unmatched in the industry." RSI's emphasis on long-term monitoring contracts and repeat clients is illustrated in the chart below.



To sustain its strong client responsiveness, RSI introduced modular services and pricing, special archive data offerings and additional custom and off-the-shelf products such as Digital Elevation Models (DEMs), mosaics and RADARMaps. In addition, strategic partnerships and licensing agreements continue to generate new products, including RADARSAT-derived DEMs produced this past year in collaboration with Atlantis Scientific Inc. and ERDAS Inc.

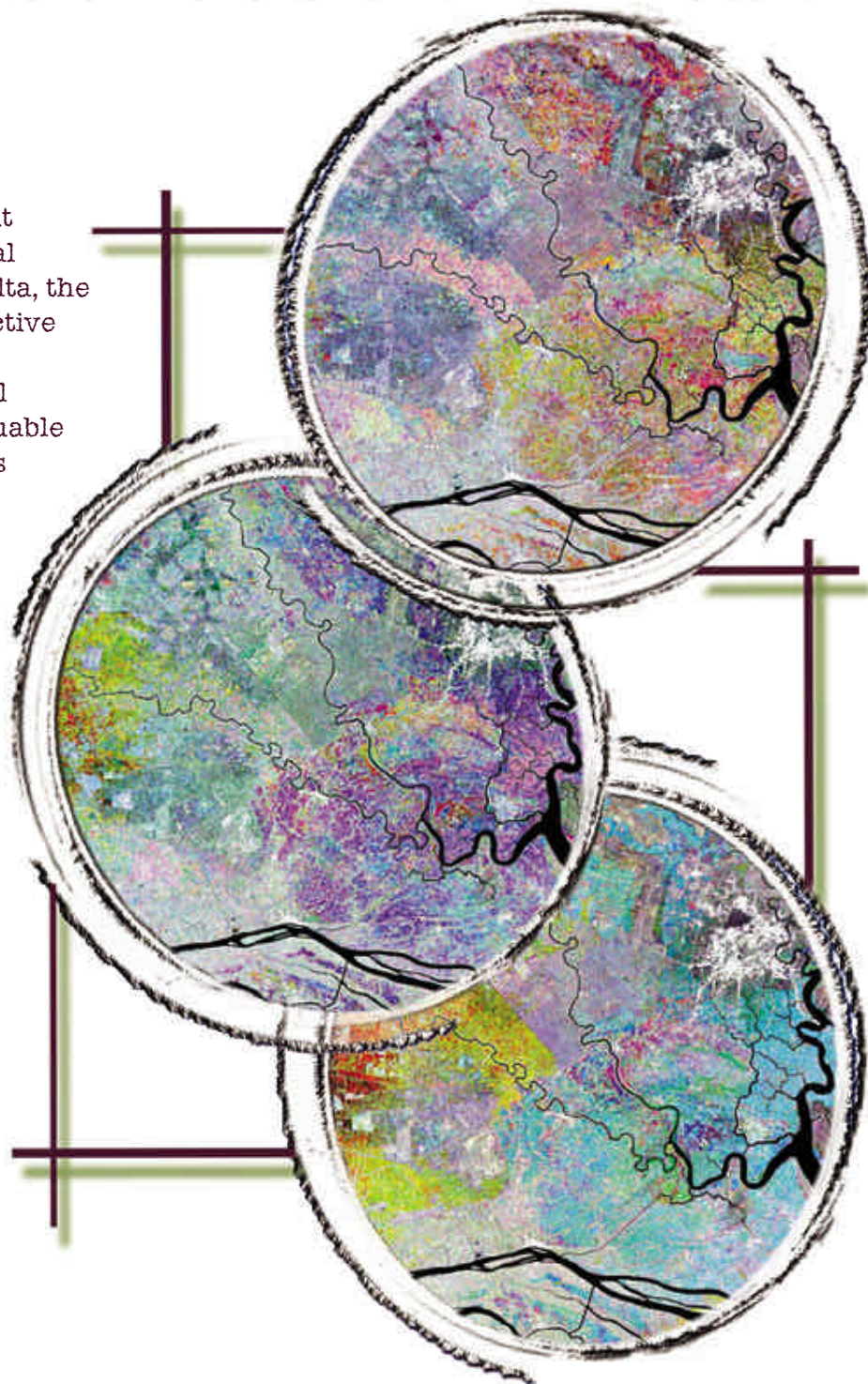
The global network of RADARSAT-1 Resource Centres expanded in 1999 to include Brazil, which joined eight other centres located in Argentina, Australia, Canada, China, France, the Netherlands, Thailand, and the United States. These regional centres, which often forge strong links between the private sector and academic institutions, deliver radar training programs, support local research projects, and monitor local RADARSAT-1 applications.



Based on the strategy of offering the best possible operational solutions, RSI is helping organizations around the world discover the benefits of deploying SAR data. Furthermore, RSI's growing suite of innovative and competitive products and client services is demonstrating why the RADARSAT-1 system is gaining recognition worldwide as the Earth observation sensor of choice.

Each year, floods deposit nutrients on agricultural fields in the Mekong Delta, the largest and most productive rice-growing region in Vietnam. Multi-temporal images like this are valuable in tracking the progress of floods and can help flood authorities assist local communities in preparing for the floods and in monitoring the affected areas. The extent of the flooding is represented in yellow/red, and intense rice growing areas are represented in purple/blue.

RADARSAT-1 data © Canadian Space Agency
1999. Received by the Canada Centre for
Remote Sensing. Processed and distributed
by RADARSAT International (RSI).
Produced and provided by RSI.



Canadian Ice Service

Throughout 1999, the Canadian Ice Service (CIS) continued to rely heavily on real-time delivery of RADARSAT-1 data in support of providing ice information to marine operators in Canadian waters. Similar to previous years, CIS received approximately 3 800 scenes in 1999. Image products delivered from this data stream numbered 43 772 while over 5 572 graphical analyses were sent to clients. All ScanSAR imagery received at CIS from the Canadian Data Processing Facility since April 1997 is archived and now forms a valuable database with over 10 000 scenes as of December 1999.

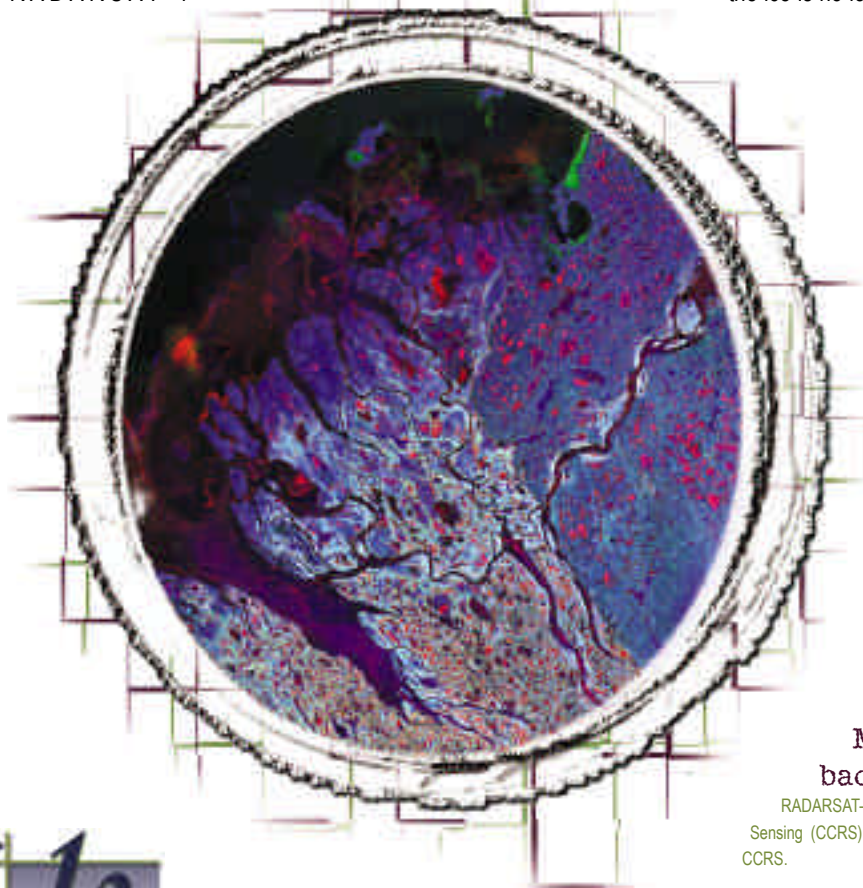
For the summer 1999 Arctic season, CIS began a trial period of sending compressed full-resolution RADARSAT-1

scenes to regional Coast Guard ice offices and icebreakers using wavelet compression technology. This effectively reduces an entire geocoded ScanSAR scene (500 x 500 kilometres) to a file less than two megabytes in size while retaining virtually all the information and image quality of the original image data. With the successful completion of these trials, CIS is now implementing a fully integrated and automated system to deliver RADARSAT-1 images to Coast Guard clients using this advanced technology.

Acquisition and use of non-ScanSAR beam modes increased again in 1999. CIS is developing an advisory system to deliver information to northern communities on the stability of land-fast ice to help determine when the ice is no longer safe

to travel on or work from. During the 1999 spring break-up season, CIS collected ScanSAR, Wide and Standard imagery over pilot communities to monitor and identify various stages of sea ice decay and ice strength.

Also initiated was an investigation into the use of RADARSAT-1 to detect icebergs off Canada's East Coast. More than 50 passes of ScanSAR Wide, ScanSAR Narrow and Wide modes were acquired, several of which were collected coincident with aircraft flights and surface validation activities. RADARSAT-derived iceberg data will augment and be integrated with information from existing data sources into the CIS iceberg database and iceberg monitoring program.



A multi-date image shows the spring ice break-up in the river channels that flow through the Mackenzie Delta in Canada's Northwest Territories. Created using Wide 2 images acquired on May 5 (red), May 29 (green) and June 15 (blue) in 1999, the composite shows the region before, during and after the ice break-up. The river channels are predominantly red due to the increased wetness of the ice and/or the overlying snow layer and the break-up and removal of ice after May 5, which produced less radar backscatter.

RADARSAT-1 data © Canadian Space Agency 1999. Received by the Canada Centre for Remote Sensing (CCRS). Processed and distributed by RADARSAT International. Produced and provided by CCRS.

Advancing Earth Observation Applications

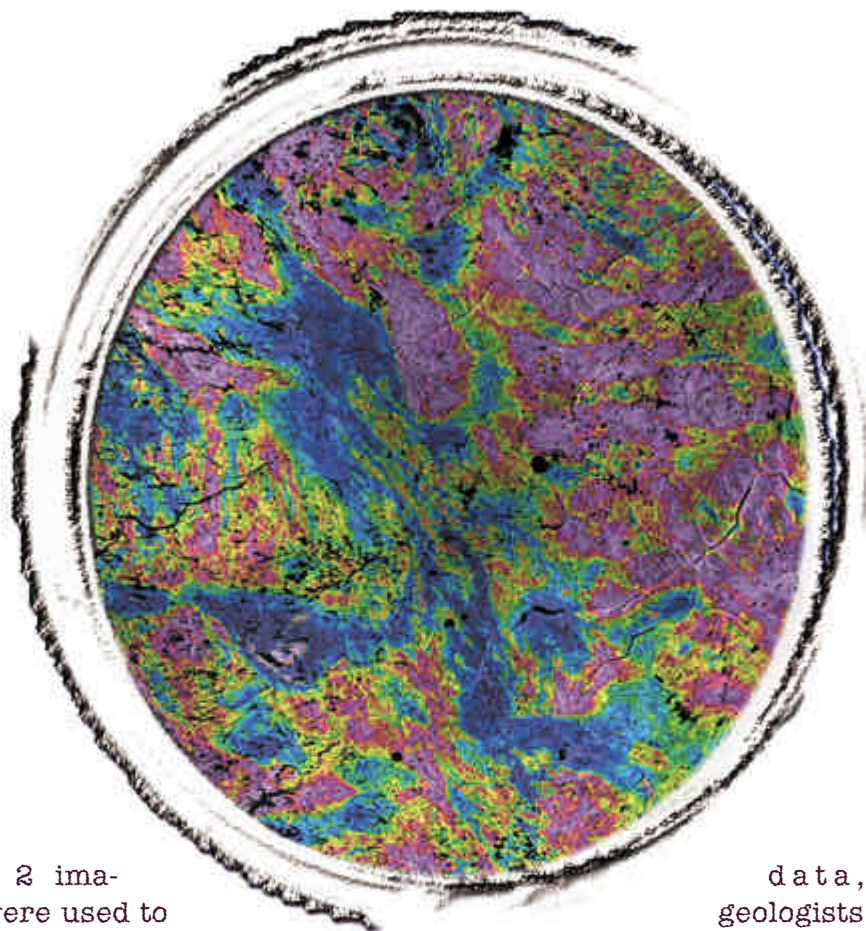
Earth Observation Application Development Program

Under the renewed Canadian Space Program, which was approved in May 1999, CSA will be funding applications development activities through a new initiative called the Earth and Environment (E&E) Service Line. E&E activities will concentrate on further expanding Canada's leadership in key areas such as resource management, disaster management and surveillance, and the environment. To develop applications in support of these activities, CSA, in collaboration with CCRS and other federal government agencies, is planning to establish an Earth Observation Application Development Program.

This new program will support applications development projects that focus on maximizing the utilization of satellite data generated by CSA-supported missions, including RADARSAT-1 and the upcoming RADARSAT-2 program. As such, it will provide continuity in terms of market and user development once the existing support programs wind down on March 31, 2000. An overview of the final results of these programs follows.

RADARSAT User Development Program (RUDP)

Nine new RUDP contracts were awarded in 1999, which support the development of innovative solutions in fields such as hydrology, forestry, and agriculture monitoring. Companies working in the areas of applications software, DEM generation, land cover classification and geological applications continue to report strong market demand for the RADARSAT-based products and services that they have developed.



Wide 2 images were used to create a georeferenced mosaic covering an area of 240 000 square kilometres in Northern Québec. The mosaic was integrated with geoscientific data to support a 1:250 000 geological mapping project. By combining the mosaic and the magnetic field

data, geologists can identify magnetic anomalies delimited by geological structures, which are greatly enhanced using RADARSAT-1 data.

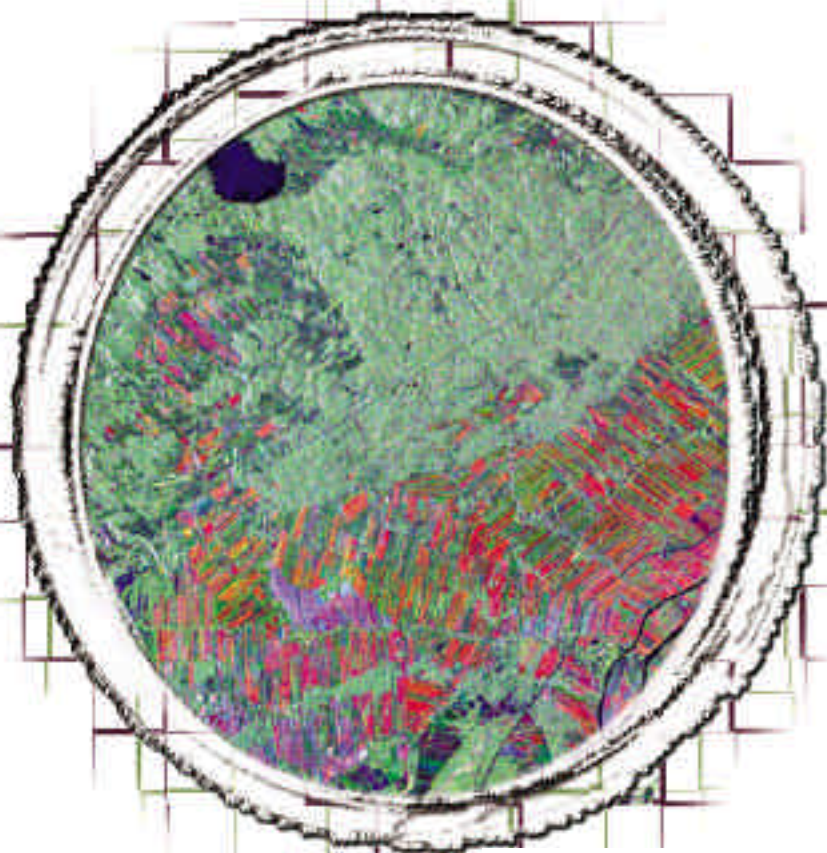
RADARSAT-1 data © Canadian Space Agency 1998. Received by the Canada Centre for Remote Sensing. Processed and distributed by RADARSAT International. Produced and provided by MIR Télédétection Inc.

RUDP Results

Total contracts:	48
Value of contracts:	\$12.3 million
Products and services generated:	28
Leveraged RADARSAT-1 products and services sales:	\$35.8 million (est.)*

*Sales figures are estimates and provided by RUDPproject participants. The estimates have not been validated by CSA at the time of publication.

Advancing Earth Observation Applications



Standard 4

(red), Standard 7 (green) and Standard 1 (blue) scenes acquired on May 28, June 10 and August 11, 1999 respectively were processed to create this multi-temporal image of Sorel, Québec. Forested and agricultural regions as well as changes in the forested areas can be discerned.

RADARSAT-1 data © Canadian Space Agency 1999. Received by the Canada Centre for Remote Sensing. Processed and distributed by RADARSAT International. Produced and provided by Geomat International.

Other benefits generated by RUDP activities

include the creation of new strategic alliances with private industry organizations as well as government agencies. The Canada-Quebec Agreement on the Development of RADARSAT Data Applications exemplifies the cooperation in supporting the development of local companies while raising awareness and bringing together government departments to develop and use RADARSAT-based products and services. Since the signing of the Canada-Quebec Agreement in 1998, four projects have been co-funded by RUDP and the Government of Quebec; another four were co-funded with EOP3.

Earth Observation Data Sets (EODS)

EODS continues to supply RADARSAT-1 data to Canadian researchers for the development of new algorithms leading to the extraction of information from image data products. Under the Announcement of Opportunity component of the program, 30 projects covering a wide range of application areas are now nearing completion.

Heather Holden of the University of Waterloo was the 1999 recipient of the EODS Marine Remote Sensing Scholarship for her project entitled "Spectral Classification of Coral Biological Vigour". Over the past year, the Action Concertée RADARSAT-1 component of the program supported six proposals covering topics including precision mapping using interferometric techniques, precision geolocation using GPS data, hydrological watershed modelling, urban change mapping, hydrometeorology, and wetland dynamics modelling. In addition, various climate change data sets were produced through industry partnerships.

Earth Observation Pilot Projects Program (EOP3)

EOP3 worked closely with other applications development programs to smoothly move project applications from research through development to operational application and acceptance by users. During 1999, 17 projects received EOP3 funding, with RADARSAT-1 data being used in geology, agriculture, forestry, hydrology, coastal, and ecological mapping applications. Four projects were included under the Canada-Quebec Agreement. In total, EOP3 has supported 49 projects, providing support to 30 different companies across Canada.

User Education and Training Initiative (UETI)

With more than 40 projects now completed, UETI partnerships have generated curriculum product deliverables that serve as critical corporate resources for successful publishing and related market development activities. UETI support is also helping companies to establish and consolidate their positions in specific target markets by using training services as a vehicle or a component of their market development strategies.

As envisioned, UETI-funded programs have produced a number of spin-off activities, including:

- formation of a new company called TerraMania, which was established by Lynn Moorman (formerly of INTERMAP) and focuses on K-12 geomatics work,
- continued support of the INTERMAP RADARSAT-1 Lesson Plan for User Education and Training, which integrates RADARSAT-1 into new and established curricula, and
- evaluation of a proposal by RSI and ThinkSpace (supported internally by CCRS) to develop computer-based geomatics exercises for use in Ontario high schools.

GlobeSAR-2

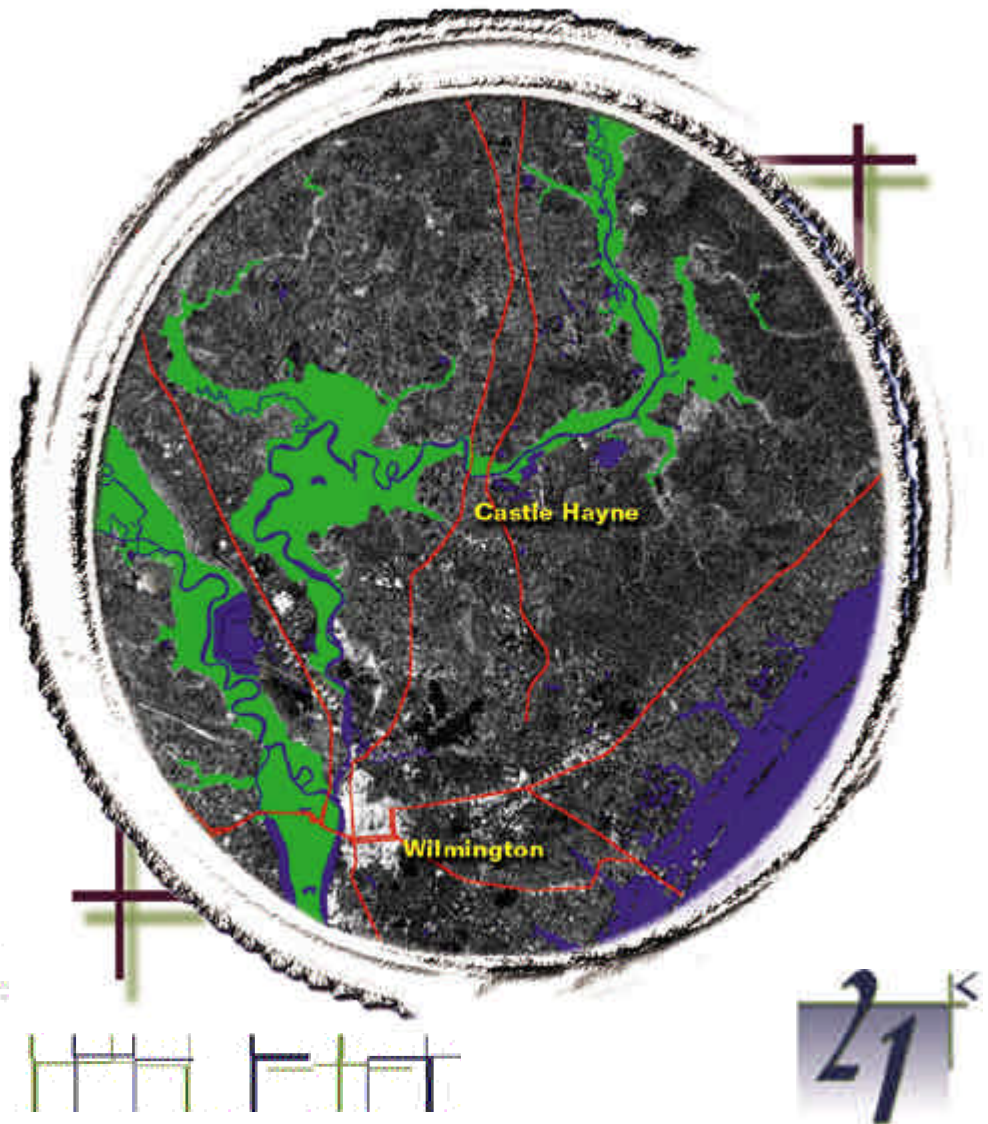
Managed by CCRS, GlobeSAR-2 is sponsored by the Canadian International Development Agency, the International Development Research Centre, RSI, PCI Geomatics Group and Atlantis Scientific Inc. A major highlight this past year was the Final Symposium which took place in Buenos Aires, Argentina, May 17-20, 1999. The

Symposium Proceedings include 69 papers and 11 abstracts, and describe the results of the application of RADARSAT-1 data for natural resource management and environmental monitoring in 11 Latin American countries.

GlobeSAR-2 participants are looking forward to RADARSAT-2 and the enhanced capabilities that will be delivered to the large Latin American user community. Discussions are now under way with potential Canadian and international partners in order to maintain an active radar remote sensing network in this region once GlobeSAR-2 concludes in 2001.

When Hurricane Floyd struck the Atlantic coast last year, its torrential rains caused wide-spread flooding that persisted for weeks. Shown in this image is an area near Wilmington, North Carolina on September 23, 1999 just days after the hurricane hit this part of the coast. Open water is blue and flooded vegetation is green.

RADARSAT-1 data © Canadian Space Agency 1999. Received by the Canada Centre for Remote Sensing. Processed and distributed by RADARSAT International. Produced and provided by Vantage Point International Inc.



Advancing Earth Observation Applications

Developments in Public Sector Data Utilization

In 1999, CSA's Satellite Operations looked at new ways to expand RADARSAT-1 data utilization at both the federal and provincial government levels in Canada. Initiatives were aimed at providing basic information, undertaking inventory or feasibility studies, supporting cost-sharing of special projects, or delivering workshops across the country, as outlined below:

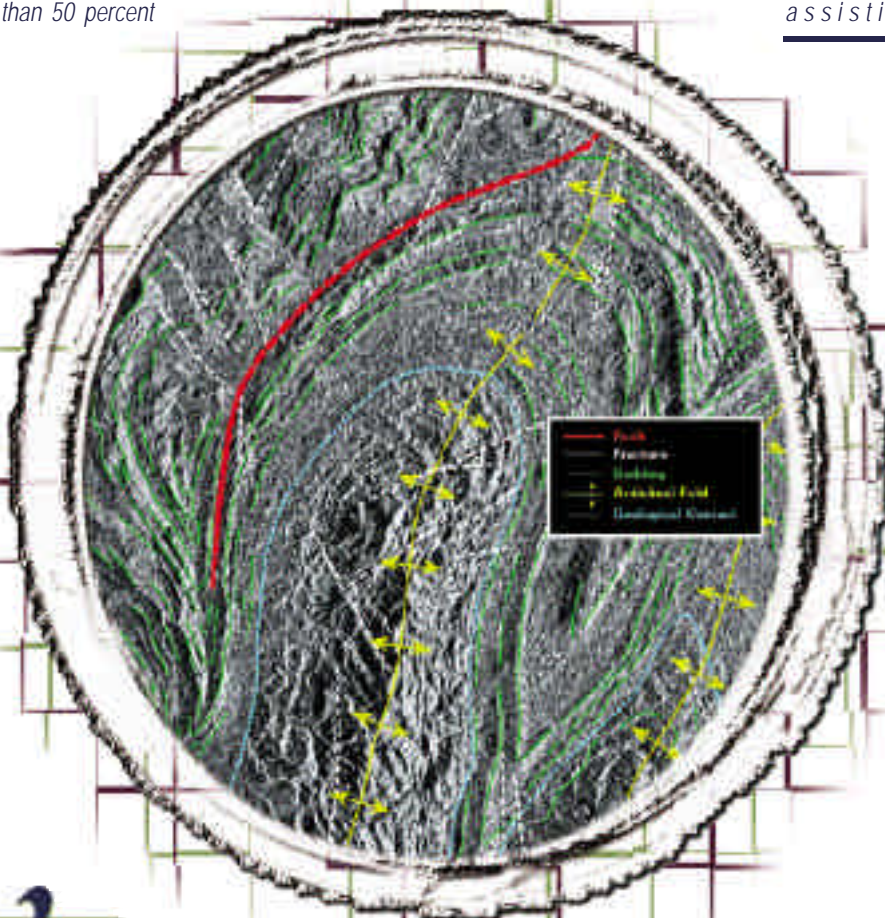
- Two independent studies revealed that nearly 100 RADARSAT-1 based products, services and tools were now available in key areas such as mapping, monitoring and surveillance. More than 50 percent

of these are now at the operational or commercial stage.

- Satellite Operations is working closely with the Department of Fisheries and Oceans (DFO) to develop a framework to integrate RADARSAT-1 data into DFO strategic decision-making and routine surveillance operations. Also, Satellite Operations joined with the Canadian Wildlife Service of Environment Canada to co-fund the production of a wetland atlas for the Saint-Lawrence River valley, a first in North America. The atlas is expected to be valuable in assisting

regional municipalities with land use planning activities.

- To facilitate the transfer of and access to information regarding specific RADARSAT-1 applications, CSA held RADARSAT-1 workshops in Halifax, Fredericton, and Toronto in cooperation with the respective provincial partners. Designed to meet the priorities and applications of a given province, the workshops were delivered in partnership with CCRS, RSI, and industry, and focused on fostering increased data utilization and generating business opportunities for industry.



Highlighted here is a spectacular Tertiary-era, thrust-folded structure of an area approximately 200 kilometres north of Bogota, Colombia. The Standard 7 image product is the result of the fusion of a DEM generated from a Standard 4 and 7 stereo pair. Geologists then interpreted Wide, Standard and Fine images, and the resulting lithostructural vector map was overlain on the RADARSAT-1 / DEM fusion image, which was used to update a 1:200 000 scale geological map of the area.

RADARSAT-1 data © Canadian Space Agency 1999. Received by the Canada Centre for Remote Sensing. Processed and distributed by RADARSAT International. Produced and provided by MIR Télédétection Inc.

RADARSAT-2:

Next-Generation SAR

Scheduled for launch in 2002, RADARSAT-2 will be the most advanced SAR satellite in the world. Carrying a next-generation, C-band remote sensing radar with a ground resolution ranging from three to 100 metres and swath widths ranging from 20 to 500 kilometres, RADARSAT-2 will be the first commercial synthetic aperture radar satellite to offer multi-polarization — an important aid in identifying a wide variety of surface features and targets.

CSA has the mandate to ensure that the Earth observation business in Canada is developed into a world-leading, profitable and sustainable business. To that end, MacDonald, Dettwiler and Associates (MDA) of Richmond, British Columbia was selected, through a competitive process, as the private sector partner for the RADARSAT-2 project by presenting a strong technical proposal as well as a strong business case.

With their lead role in building RADARSAT-2, MDA is demonstrating the private sector's commitment to the long-term evolution of the Earth observation business in Canada. Moreover, the RADARSAT-2 project will stimulate manufacturing and competitiveness in the Canadian aerospace industry as well as further development of the value-added sector. Recent program changes enabled MDA to award Alenia Aerospazio of Italy in December 1999 the contract to build the RADARSAT-2 satellite bus through an international competition. As one of



Europe's leading space companies, Alenia Aerospazio has acquired considerable expertise in constructing microwave sensors including radar altimeters, radiometers and SARs for the ESA Earth observation satellites.

RADARSAT-2 will not only assure RADARSAT-1 users of data continuity, it will also contribute valuable new information on the planet's natural resources and the global environment. Furthermore, through a unique public-private sector partnership, the RADARSAT-2 project will maintain Canada's leadership in the Earth observation business sector.

Acquired by the CCRS CV-580 SAR aircraft, this image of an agricultural site near Canada's capital city of Ottawa is being used to investigate the sensitivity of multi-polarized (HH, HV, VV) and polarimetric SAR to crop conditions for wheat, soybean and corn. RADARSAT-2 will be the first commercial SAR satellite to offer multi-polarization — a key tool in identifying a wide range of surface features.

Data received and processed by the Canada Centre for Remote Sensing (CCRS), 1998.




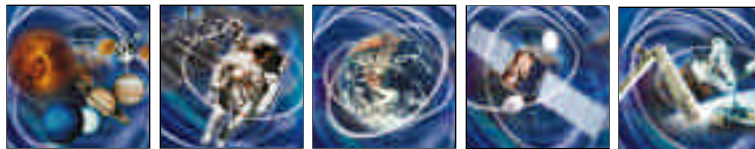


The mandate of the Canadian Space Agency is to promote the peaceful use and development of space, to advance the knowledge of space through science, and to ensure that space science and technology provide social and economic benefits for Canadians.

The Canadian Space Agency (CSA) is committed to leading the development and applications of space knowledge for the benefit of Canadians and humanity.

To achieve this, CSA promote an environment where all levels of the organization will:

- pursue excellence collectively,*
 - advocate a client-oriented attitude,*
 - support employee-oriented practices and open communications,*
 - commit to both empowerment and accountability, and,*
 - pledge to cooperate and work with partners to our mutual benefit.*
- 



*Canadian Space Agency
6767 route de l'Aéroport
Saint-Hubert, Québec
J3Y 8Y9 Canada
Tel: +1 (450) 926-4351
Fax: +1 (450) 926-4352
www.space.gc.ca*

